



# Ocean Worlds Exploration

May 2017

Solar System Exploration Directorate

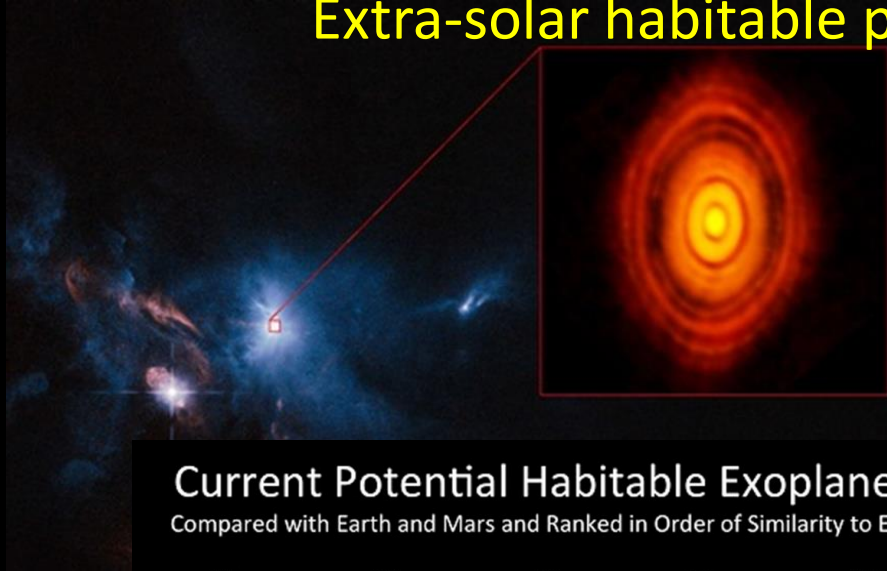


**Jet Propulsion Laboratory**  
California Institute of Technology

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# Is there life somewhere else in the Universe?



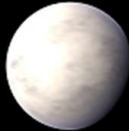
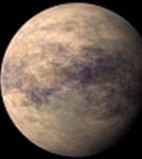
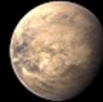
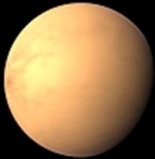

## Extra-solar habitable planets



### Current Potential Habitable Exoplanets

Compared with Earth and Mars and Ranked in Order of Similarity to Earth

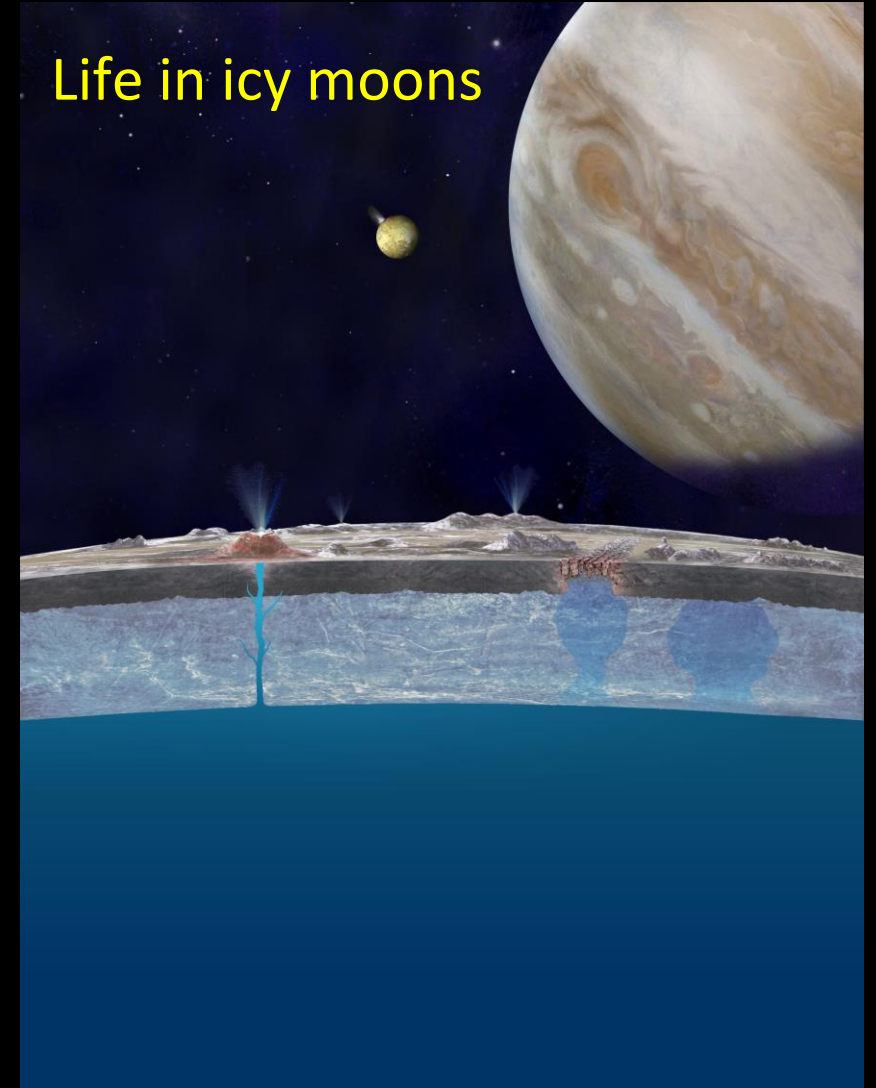
Earth 1.00 Mars 0.66

#1	#2	#3	#4	#5	#6	#7
0.92	0.85	0.81	0.79	0.77	0.73	0.72
			Earth Similarity Index			
						
Gliese 581 g*	Gliese 667C c	Kepler-22 b	HD 40307 g*	HD 85512 b	Gliese 163 c	Gliese 581 d
Sep 2010	Nov 2011	Dec 2011	Nov 2012	Sep 2011	Sep 2012	Apr 2007
Discovery Date						

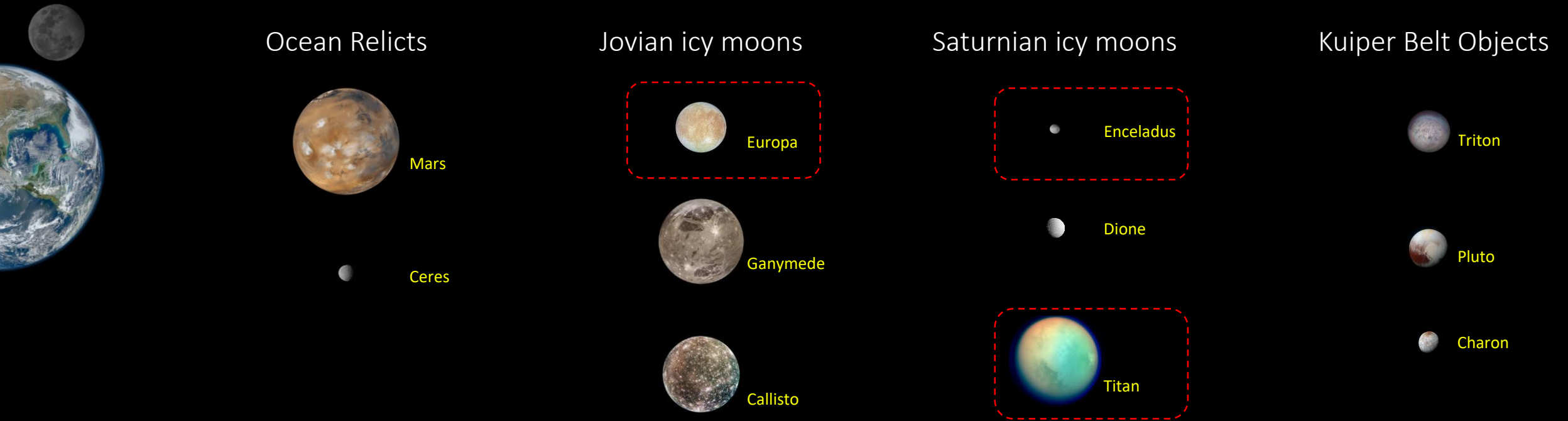
\*unconfirmed planets

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Nov 7, 2012

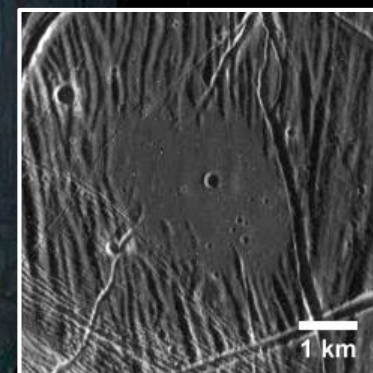
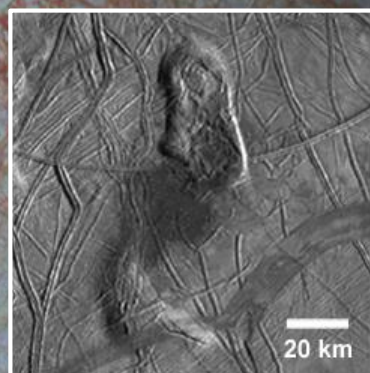
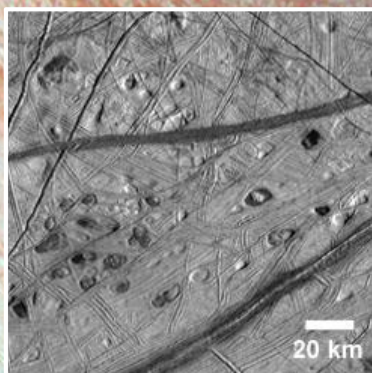
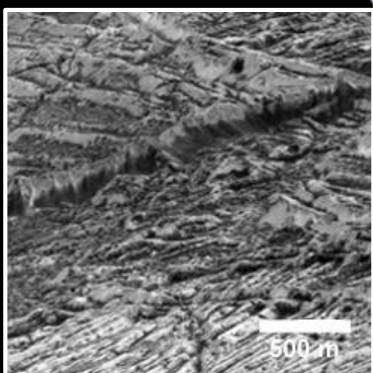
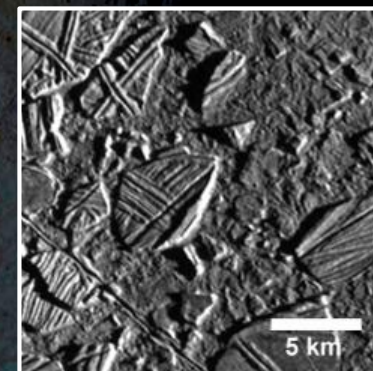
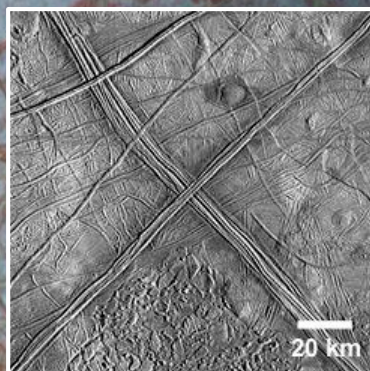
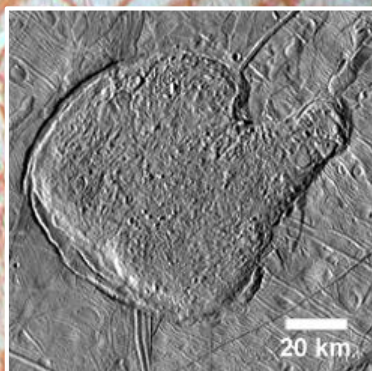
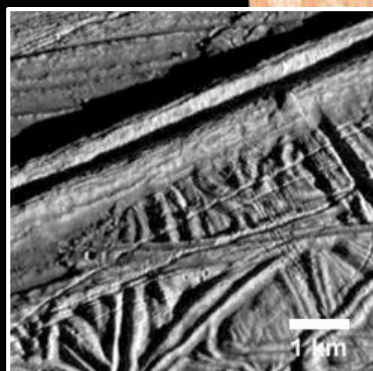
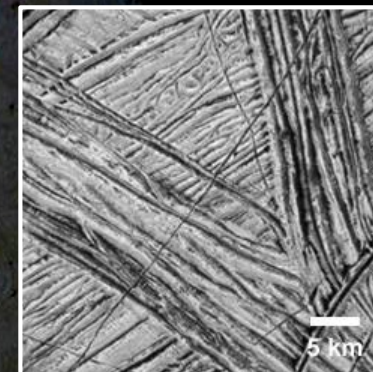
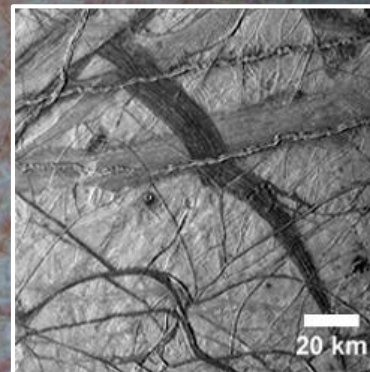
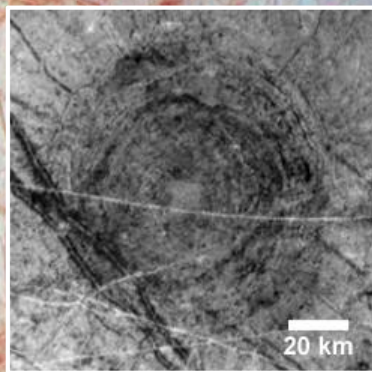
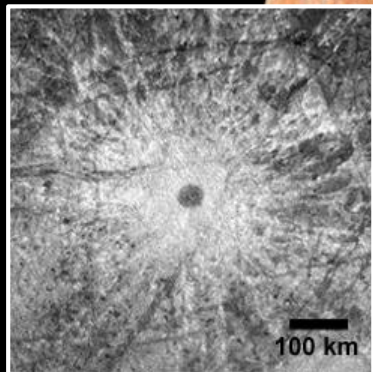
## Life in icy moons



# Mission Target Priorities





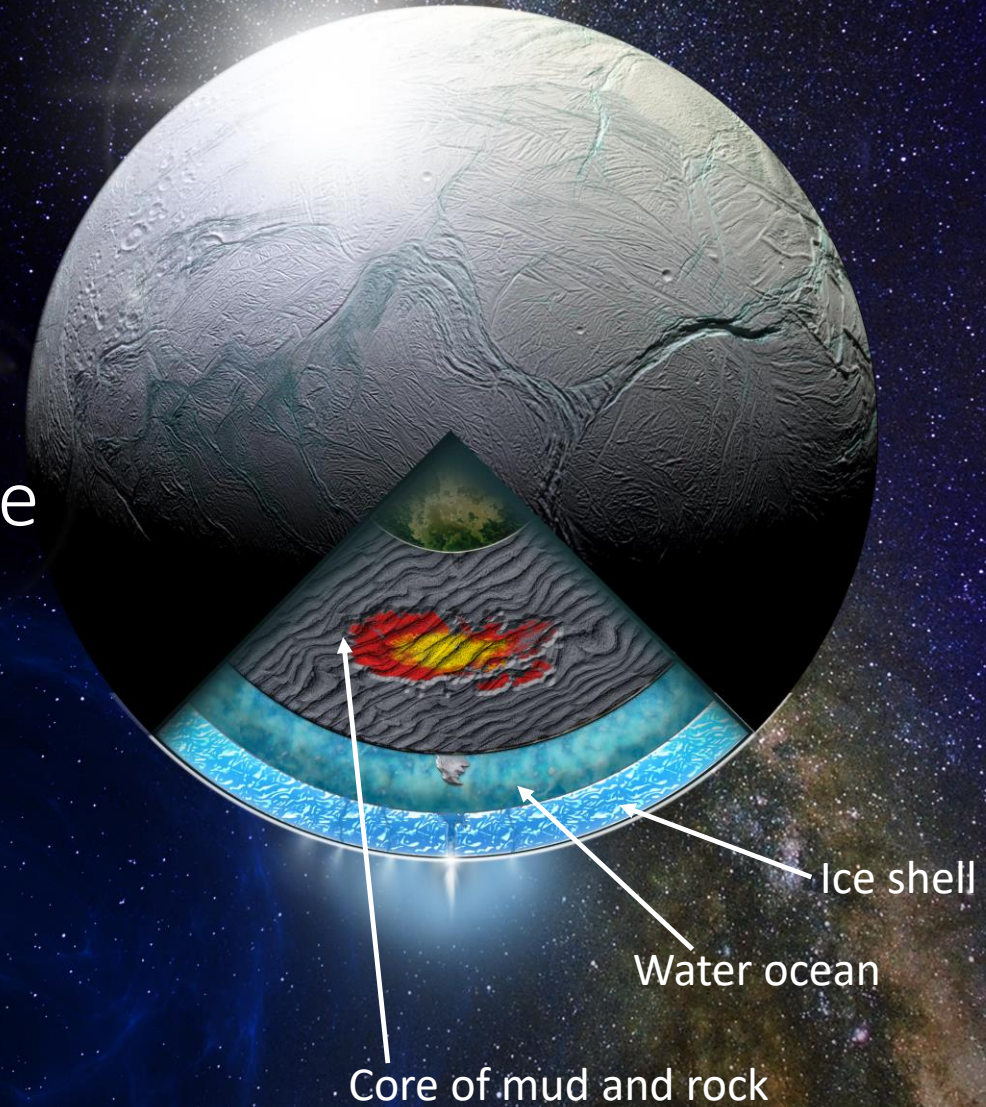




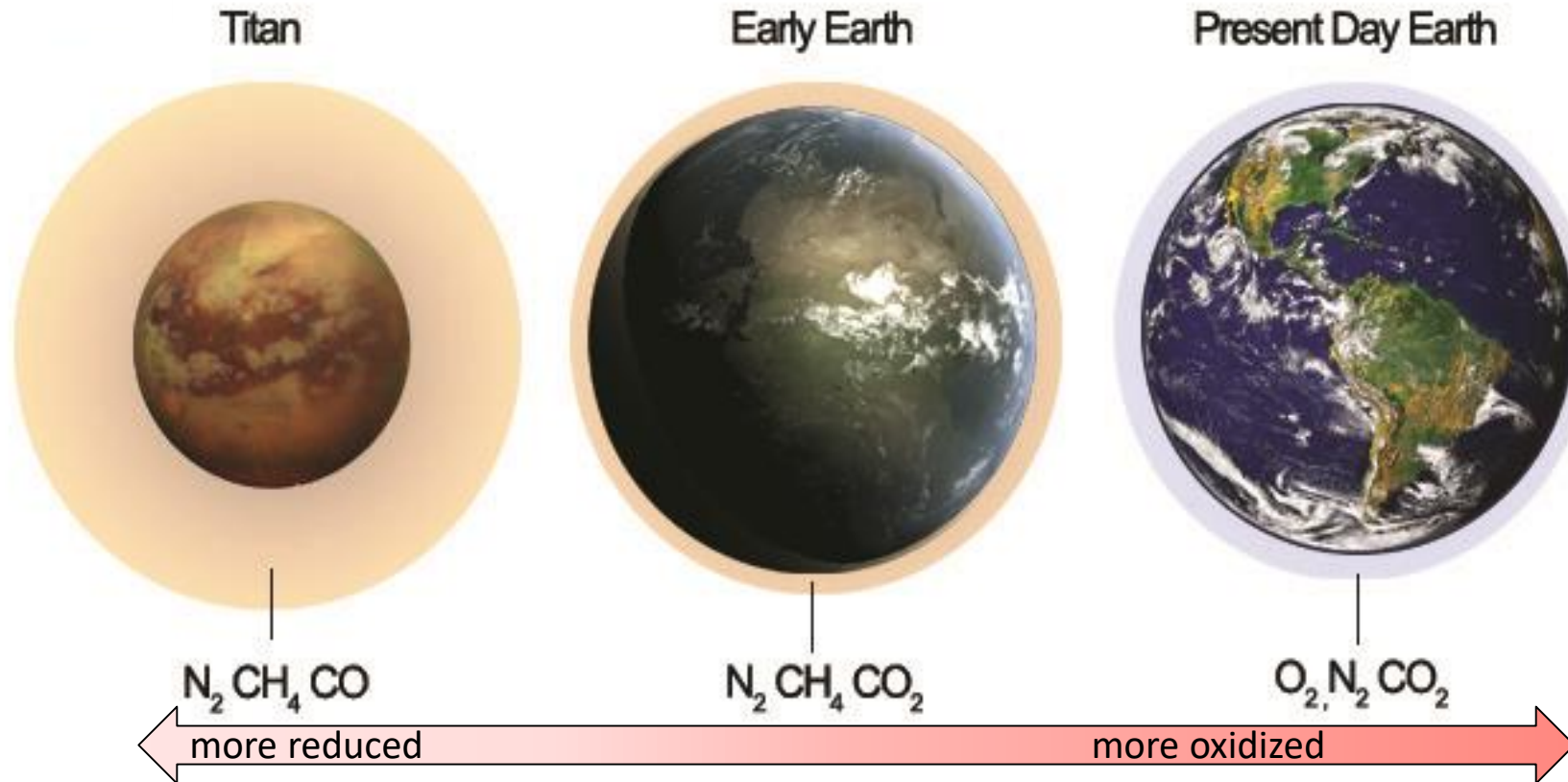
# The Case for Enceladus

Cassini has

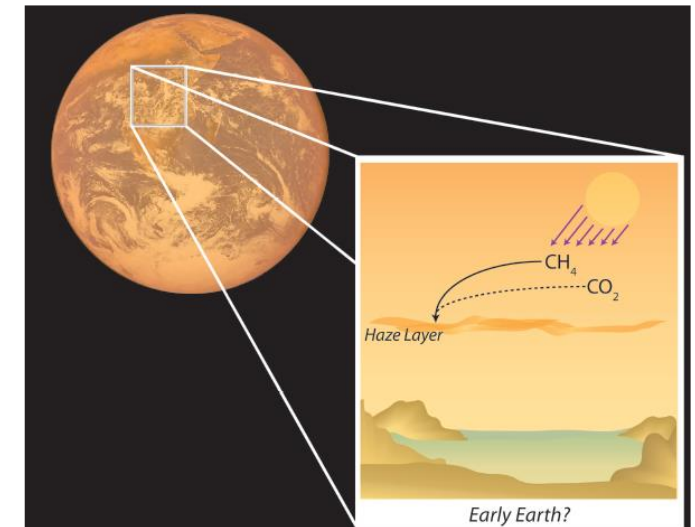
- Discovered a global interior ocean
- Flown *seven times* through its large plume
  - Detected salts, and thus ocean grains
  - Measured a variety of organic molecules
  - Found multiple lines of evidence for hydrothermal activity at the ocean's base



# Analog for organic chemistry on the Early Earth

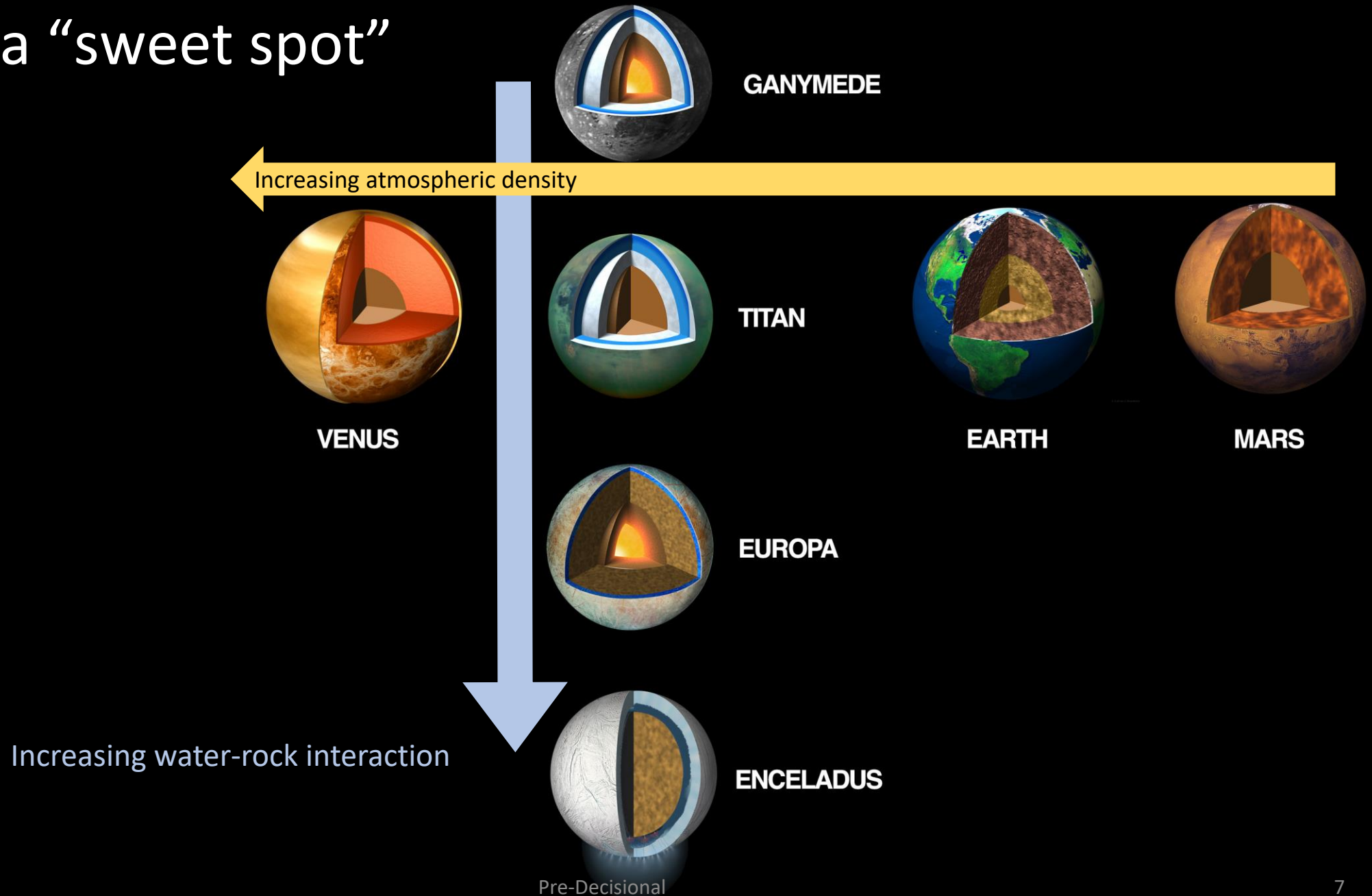


**How was organic material delivered into Earth's ocean as life was emerging about 4 billion years ago?**





# Titan is a “sweet spot”



# First program steps

Europa



- ✓ Orbital Recon – **Planned Clipper Mission**
- ✓ Surface In Situ – **Lander Concept**

Titan



?

Ocean Worlds theme in  
**New Frontiers-4** competition,  
Step 1 proposals due 4/28/17

Enceladus



?

## OW Technology Investments

- \$25M appropriated in FY16
  - 16 2-yr ~\$1.5M COLDTech study projects
- ✓ Plume Sampling System (Adams, APL)
  - ✓ Integrated Sampling System (Zacny, Honeybee Robotics)
  - ✓ Supercritical CO<sub>2</sub> Extraction and Chromatography (Henderson, JPL)
  - ✓ Microfluidic Sample Processor (Ricco, ARC)
  - ✓ Europa molecular analyzer (Brinckerhoff, GSFC)
  - ✓ Luminescence Imager (Quinn, SETI Inst)
  - ✓ Nuclear Mag Resonance spectrometer (Hammer, Univ MN)
  - ✓ Nanopore Sequencing for Life Detection (McKay, ARC)
  - ✓ Nanomotion Sensor for Active Life (Murray, Desert Research Inst)
  - ✓ Lightweight Imagers (Byrne, Univ AZ)
  - ✓ Lander Imager (Maki, JPL)
  - ✓ Ionic liquid miniature Seismometer (Yu, ASU)
  - ✓ Distributed Motor Controller (Bolotin, JPL)
  - ✓ Laser Melt Probe (Stone, Stone Aerospace)
  - ✓ Jetting Melt-Probe for dirty ice (Winebrenner, Univ WA)
  - ✓ Sensing for undersea exploration (Wong, Intelligent Robotics Group)



# Shared infrastructure

## Notional SLS launch

- 2-3 years to Jupiter orbit (Clipper)
- Enabling for Europa Lander
- 5-6 years to Saturn orbit

May 2017

Pre-Decisional

## High-power SEP

- Comparable trip times using standard LVs
- Scalable *down* for \$1B-class missions

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# Key technologies common to the key targets

- Planetary protection of and from ocean-world material
- “Life-detection” measurement techniques and instruments
- Sample acquisition, handling, preservation
- Cryogenic mechanisms and electronics
- Modular radioisotope power sources
- Autonomous exploration and science investigation



# Melt Probe Concept

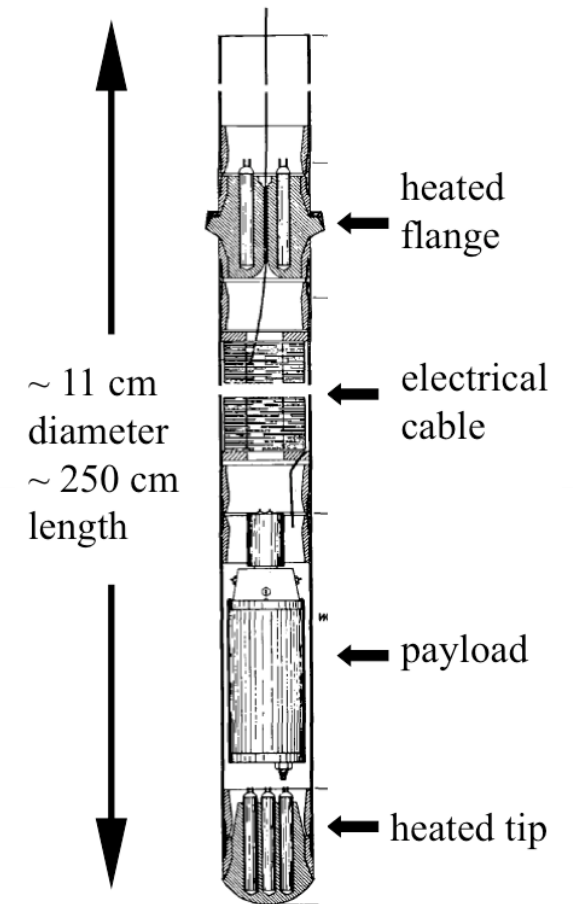
National Aeronautics and  
Space Administration



Melt probes have been used to explore ice for over 50 years on Earth



Winebrenner et al

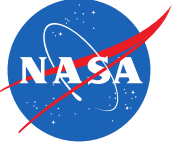


Philberth Probe



# Water-Jet Probe Concept

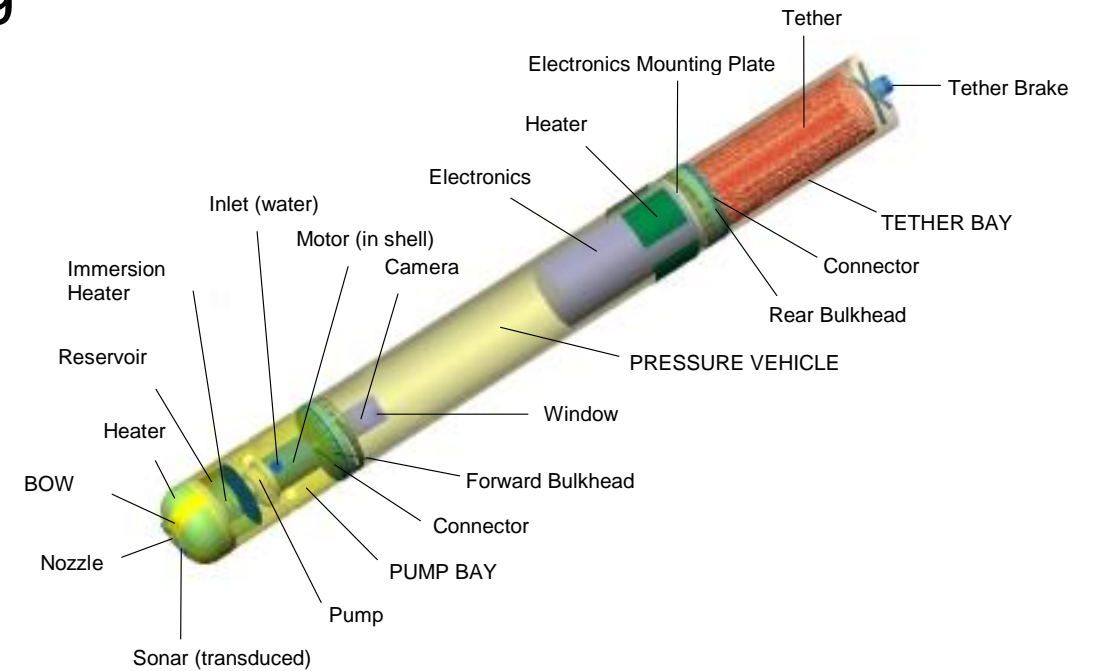
National Aeronautics and  
Space Administration



## Melting + High Pressure Water Jetting



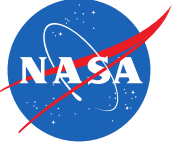
Zimmerman et al



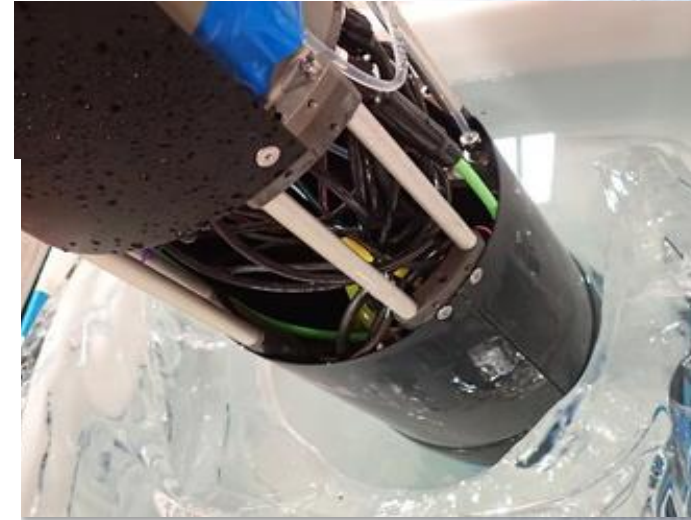
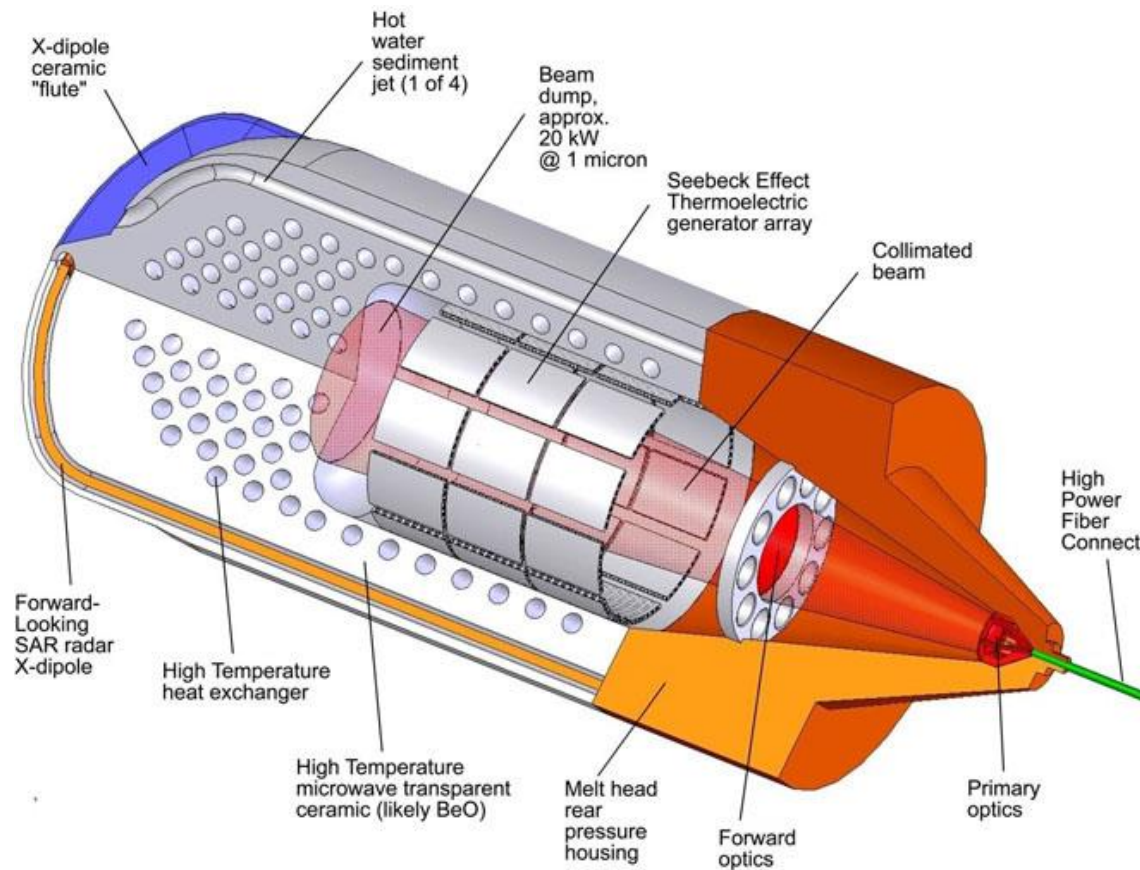


# Laser Heated Probe Concept

National Aeronautics and  
Space Administration



## Melting + High Pressure Water Jets + Laser Power Delivery



May2017

Pre-Decisional

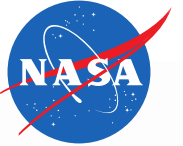
Stone et al

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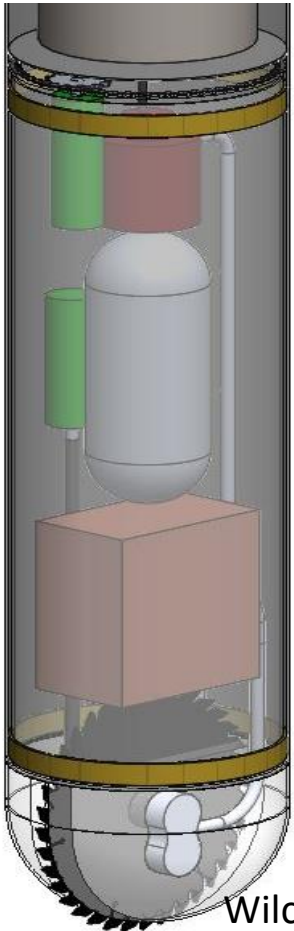


# Mechanical Probe Concept

National Aeronautics and  
Space Administration



## Mechanical cutting + Focused Melting



Wilcox et al

